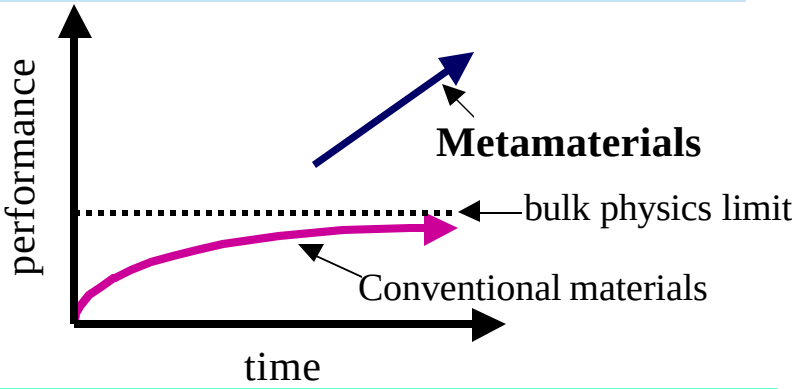
# ***Meta-Materials***

***"Metamaterials" are engineered (nano) composites that exhibit superior properties that are not found in nature and not observed in the constituent materials.***

# *Metamaterials: Changing the design paradigm*

## ***Problem***

The ultimate performance of conventional bulk materials is limited by physics.

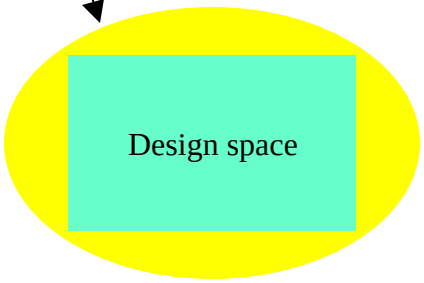



## ***Solution***

Metamaterials: New physics = enhanced performance

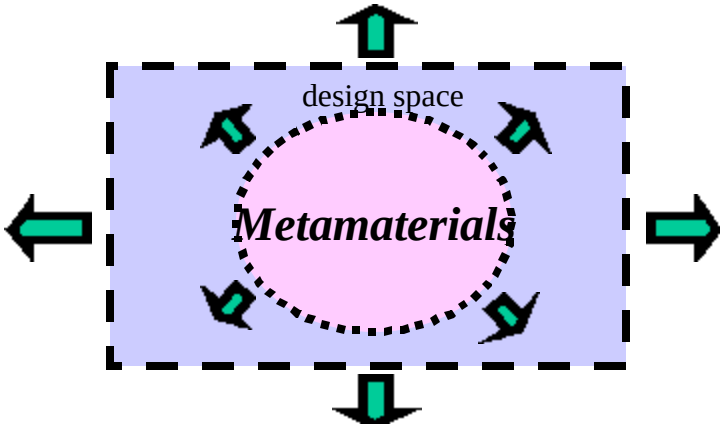
**Design Constraints**

Materials' limitations




***METAMATERIALS***

**Design Freedom**

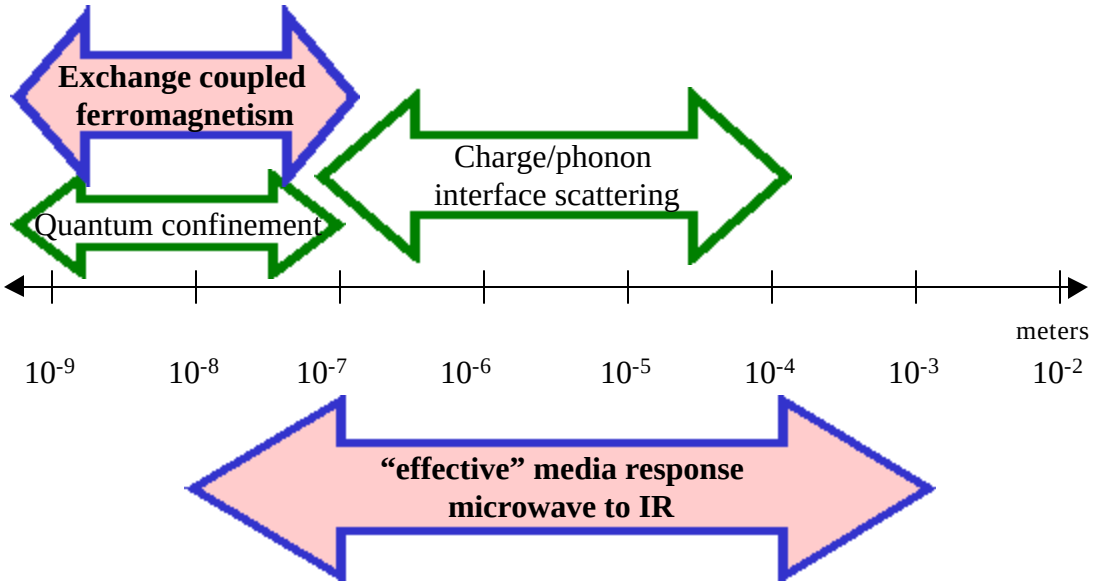


# Why Metamaterials?

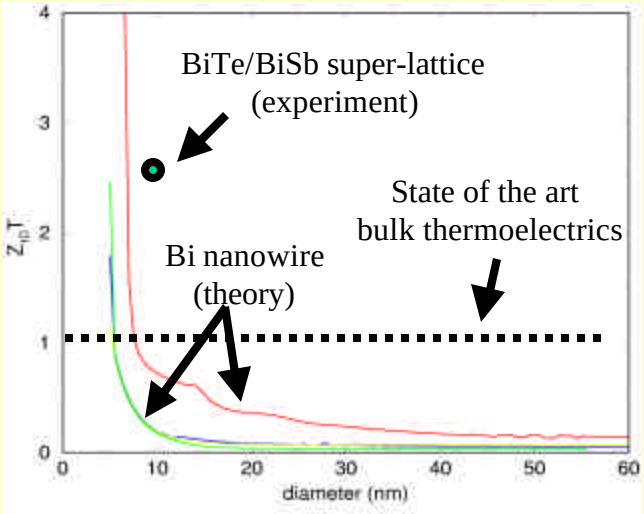
… ***because the physics at "small" scales is different, interesting, and in many cases, better from a performance perspective***

**METAMATERIALS OBJECTIVE**

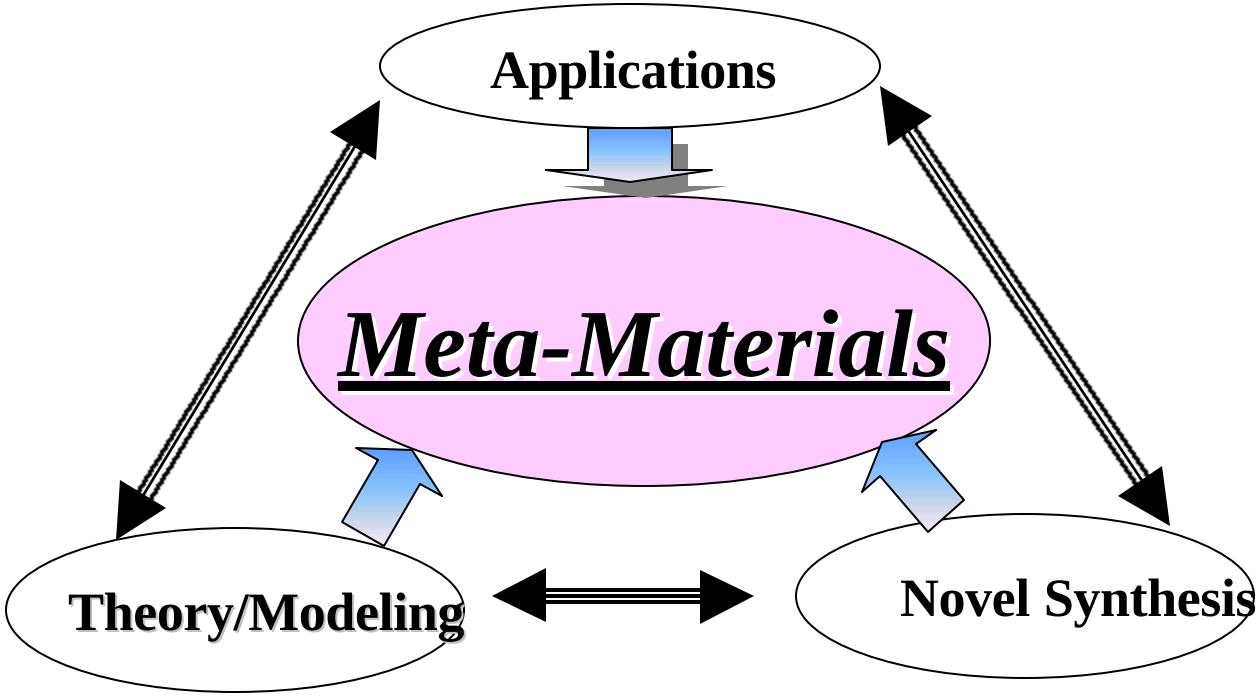
***Preserve the superior properties of low dimensional systems in new bulk materials constructed frpm unit cell building blocks that are engineered to exploit "small" scale physics***




***Example**: Thermoelectric figure of merit ($ZT = S^2T/\rho k$)*



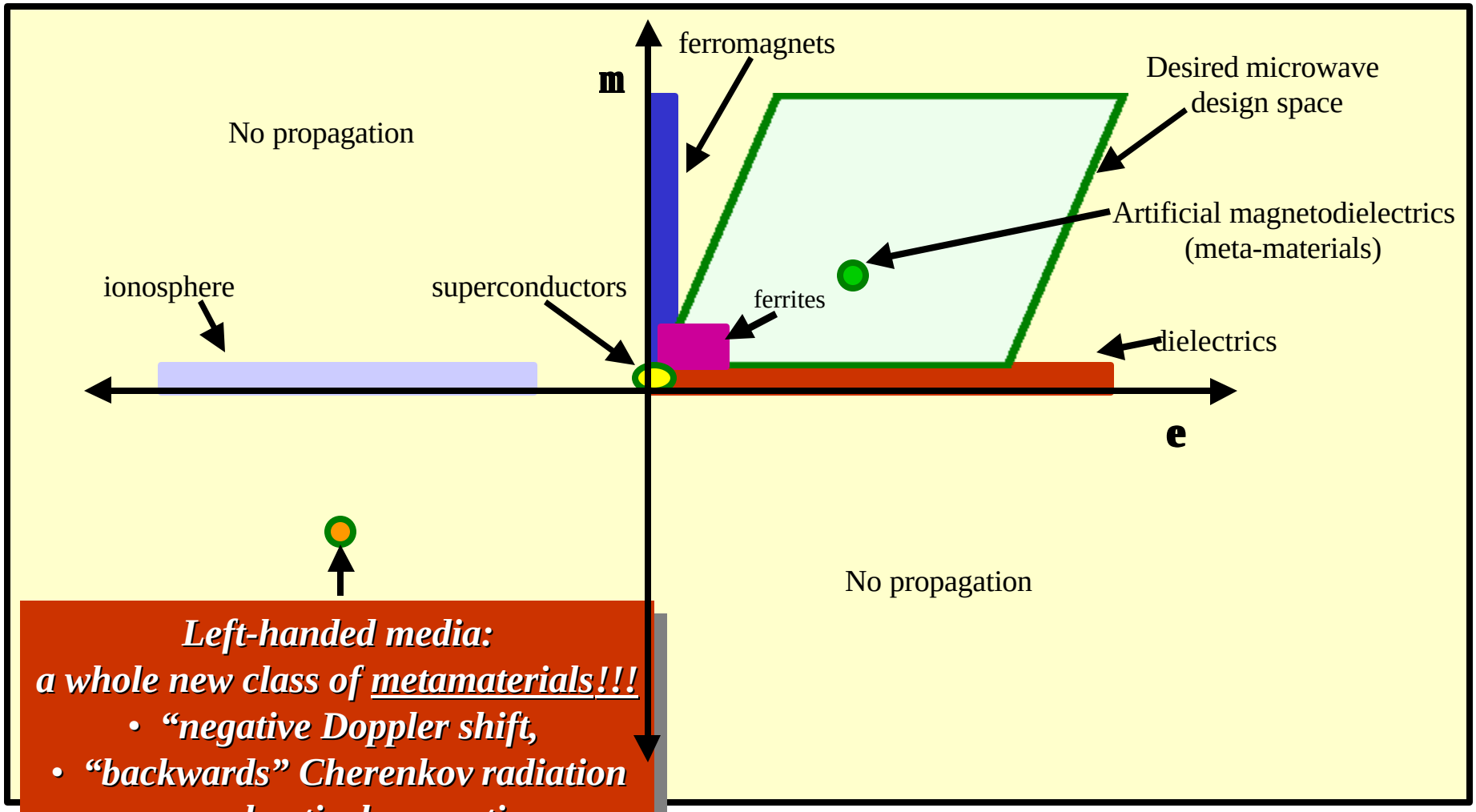
# The Metamaterials Program




***Metamaterials will deliver:***

- low frequency (< 1 MHz) meta-materials with superior magnetic properties for power electronics, electric propulsion, and power generation
- high frequency (> 1 MHz) meta-materials with superior microwave and/or optical properties for communication, radar, and wireless power transfer applications.

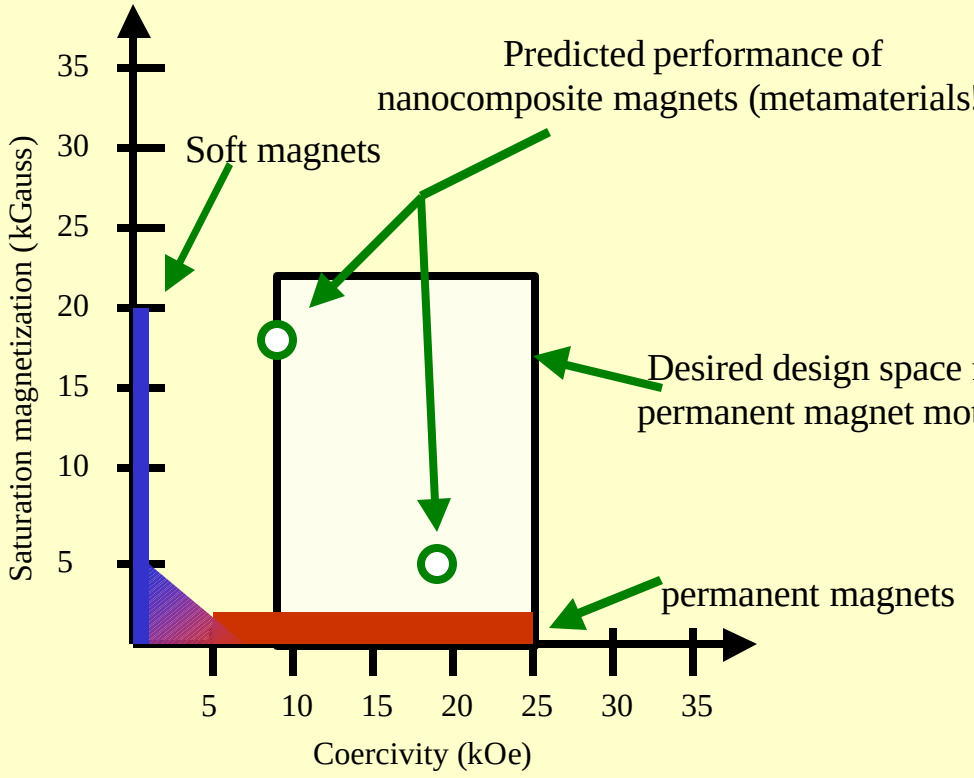
# *Metamaterials: Filling the void in the microwave design space*

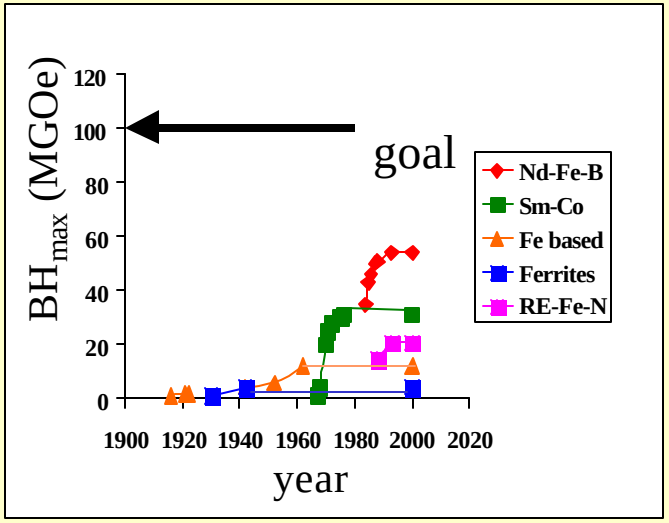



***Left-handed media:***
***a whole new class of <u>metamaterials</u>!!!***

- ***"negative Doppler shift,***
- ***"backwards" Cherenkov radiation***
- ***novel optical properties***

# *Magnetic nanocomposites (metamaterials) will enable electric drive/propulsion*

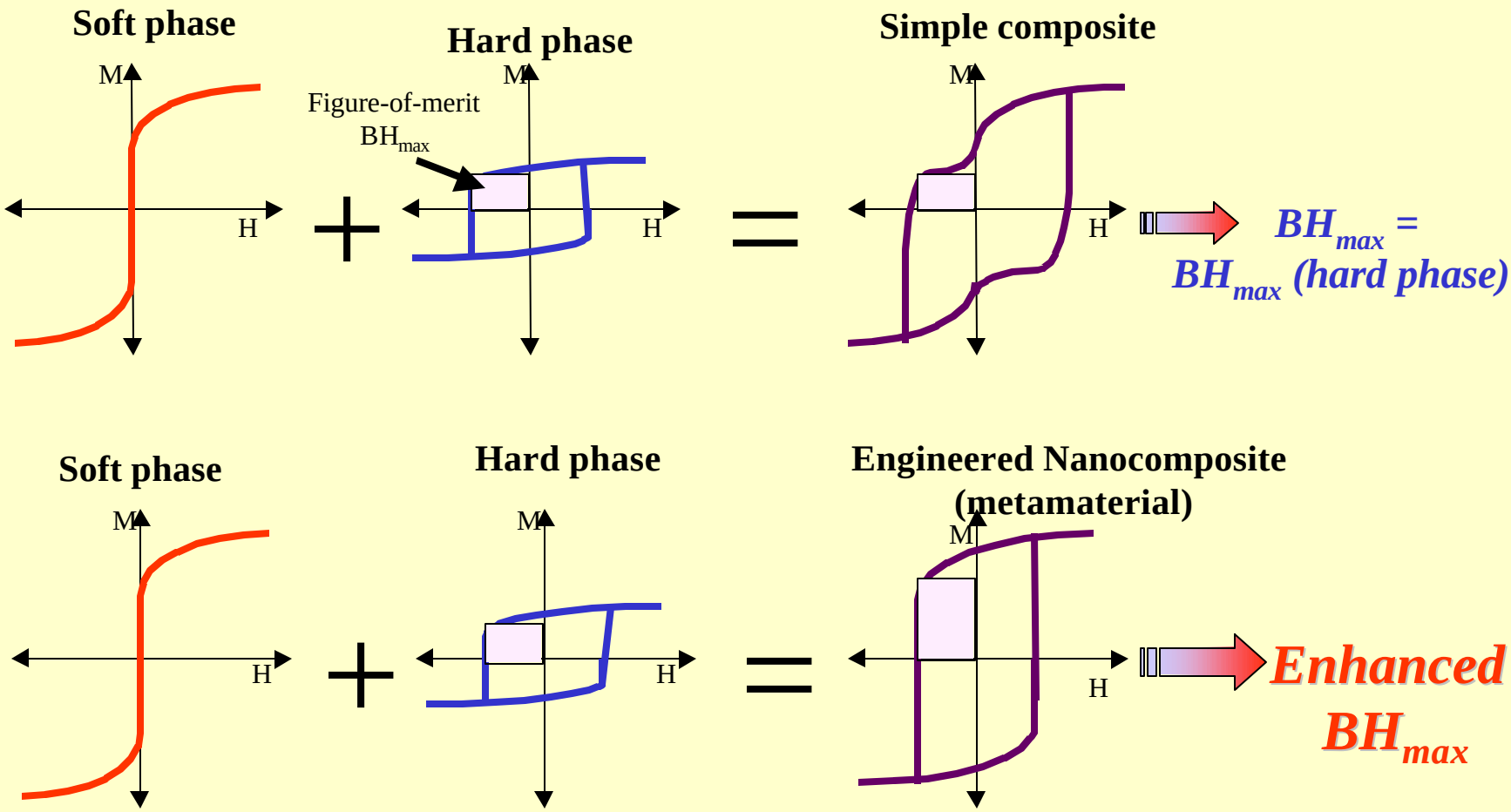



***Low cost ($5-$10/lb), high performance, permanent magnets will enable:***

- electric drive (tanks, automobiles)
- quieter, more efficient motors (UUV propulsion)
- permanent magnet biased bearings
  (lubeless motors/generators)
- open MRI
- faster spindle motors for hard drives
  (hard drive capacity increases 60 %/ year)

# The Metamaterials Approach to Magnetism: Nanocomposite Exchange Magnets



# *Meta-Materials Critical Program Elements*

***Theoretical challenges to understanding/predicting meta-material behavior:***

- Develop more fully the theory of wave propagation in "left-handed" meta-materials
- Understand/model ferromagnetic exchange in 3-D magnetic nanocomposites
- Extend complex/effective media theory to novel 3-D meta-materials for high frequency applications

***Materials development challenges:***

- Develop algorithms for designing meta-materials given a desired response
- Identify, develop, and optimize processing schemes for fabricating meta-materials
- Develop and characterize new meta-materials with superior electromagnetic properties

***Technology demonstration/transition:***

- Demonstrate the superior/novel microwave or optical properties of meta-materials for a radar or telecommunications application
- Demonstrate the superior properties of bulk magnetic meta-materials in a power electronic, electric propulsion, or power generation application.

# Meta-Materials "Criteria"

- What type of material do you propose to develop and demonstrate?
- Is it a meta-material?
  - Is it a composite? What are the constituent materials?
  - What guiding theory will provide the "blueprint" for engineering your meta-material?
  - What are the predicted superior properties?
  - Can it (or will it) be possible to make your meta-material?
- Is your meta-material novel and unique? i.e. has it already been done or is it being done now?
- What is (are) the military application(s) that have a need for your proposed "meta-material"?
- Do these applications fall within the general application areas listed in the BAA/PIP?
- What is the material figure-of-merit for these applications? What are the current limitations on this figure-of-merit? By how much will your meta-material exceed these current limitations?
- How will you test your meta-material?
- If successful, what new and or enhanced capabilities will your meta-material bring to the military applications you've identified?
- What prototype development efforts will demonstrate the significant advantage(s) of your metamaterial?